

## DESCRIPTION

## POLYPEPTIDE

5

TECHNICAL FIELD

The present invention relates to a polypeptide having an antigenic epitope, which efficiently induces the production of an antibody specific to the antigenic epitope when per mucosally administered even in the absence of an immunological adjuvant, a composition comprising the polypeptide, and use thereof, more particularly, to a polypeptide designed by linking a polypeptide comprising a B cell epitope of a protein as an antigen for the production of an antibody specific to the protein to a T cell epitope with a linker peptide comprising amino acid sequence of a protease recognition site, and further linking a peptide comprising an amino acid sequence of a cell attachment motif, which efficiently induces the production of an objective antibody, and a composition comprising the polypeptide, and use thereof.

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BACKGROUND ART

In order to induce the production of an objective antibody specific to an antigen in living bodies, a purified antigen has been conventionally administered alone or along with an immunological adjuvant (which means a substance enhancing the immunological reaction specific to an antigen by non-specific stimulation of immune system) to living bodies. Such method has frequently used for preventing

various infectious diseases, and been considered as the most effective method because it is also effective even in the case of treating antibiotic-resistant diseases such as diseases caused by viruses or toxins produced from microorganisms. Particularly, in such case, the method thought to be the only effective treatment because it enables to defend the living bodies from such diseases by inducing the production of objective antibodies specific to viruses and toxins. At present, the method is practically applied to produce vaccines including inactivated vaccines (inactivated microbes without infecting activity, which are prepared by treating with an organic solvent or irradiating UV) and attenuated vaccines (attenuated pathogens with a weak pathogenicity against living bodies). The almost vaccines (except polio vaccines) have been parenterally administered by injection. Some inactivated vaccines, however, have problems of significant affection to living bodies and less convenience because they require successive injection for several times to obtain sufficient antibody titer to attain a satisfactory biophylaxis.

While, live vaccines such as the attenuated vaccines have problems that they have a low preservation-stability and a possibility to become harmful virulent mutants after administered to affect living bodies. Both of the inactivated vaccines and the live vaccines must be concerned to be unsafe because they may give an anaphylactic shock to living bodies. Further, human serum albumin or gelatin has been conventionally used as a stabilizer and often added to vaccine preparations containing instable virus particles or huge sized proteins as immunogens to improve the stability of the vaccine preparations. However, such substances must be also concerned to be unsafe because they possibly bring unknown infectious microorganisms

or anaphylactic shock. Most of the vaccine preparations have been produced for injection use. However, vaccine preparations have been required to be more stable and applicable without injection in order to be commercialized widely all over the developing countries where  
5 many people are dying of infectious diseases.

To solve the above problems, new type vaccines, having higher safeness and efficacy than conventional inactivated vaccines or live vaccines, has been eagerly studied all over the world by using a polypeptide comprising a partial amino acid sequence of an inactivated  
10 vaccine or live vaccine. Such new type vaccines are developed as B type hepatitis viral vaccines such as a recombinant vaccine and component vaccine. Peptides used as new type vaccines are usually desired to be a short fragment. However, excessively short fragments are difficult to be designed to have a broad major histocompatibility  
15 antigen (hereinafter, abbreviated as "MHC") class II restriction and satisfactory immunogenicity. While, in a view of enhancing immunogenicity of an objective antigen by permucosal administration, Lavelle, E.C. proposed in *Immunology*, Vol.99, pp.30-37, (2000) an immunizing method of an antigen with an immunological adjuvant such as  
20 cholera toxin (abbreviated as "CT", hereinafter), heat-instable type of enterotoxin from *E.coli*, or attenuated proteins thereof prepared by replacing a part of the amino acid sequence of CT or enterotoxin. The method enables to obtain a sufficient induction of the objective antibodies. However it has not been practical because it undesirably  
25 brings the induction of antibodies specific to CT and heat-instable type of enterotoxin from *E.coli* as immunological adjuvants.

Dental caries and periodontal diseases are considered as the two major diseases caused by microorganisms in dental field. Since such

diseases are universal and less critical, they should be prevented and treated under the highest safeness. As examples of the methods for preventing dental caries, Japanese Patent Publication Kokai No. 122,633/94 discloses a passive immunizing method using an antibody  
5 obtained from an animal immunized with a peptide fragment of a tooth surface adhesive protein from *Streptococcus mutans*, and Japanese Patent Publication Kokai No. 511,422/02 discloses an anti-dental caries vaccine composed of a T cell epitope and a B cell epitope of glucan binding protein from *Streptococcus mutans*.

10 The present inventor had studied for the purpose of developing a short polypeptide which efficiently induces an antibody specific to cell surface protein antigen from *Streptococcus mutans* serotype C strain (It is abbreviated to "PAC", hereinafter.), which relates to early phase adhesion to the tooth surface, for many individuals having  
15 different MHC class II haplotype by permucosal administration even in the absence of immunological adjuvant. In the detail field, for the purpose of enhancing the production of antibodies capable of preventing dental caries, the inventor proposed to design the short polypeptide in the manner of linearly linking a T cell epitope having  
20 multiple restrictions from several MHC class II haplotypes to N-terminus of the partial amino acid sequence of PAC at the positions of 365 to 377 (SEQ ID NO:1) as a B cell epitope with a dipeptide linker such as a lysine-lysine sequence (Nishizawa. T., Imai, S., and Hanada, N., *Japanese Vaccine conference program abstract*, p.77, (2000), Oishi  
25 Y. et al., *Oral Microbiology and Immunology*, Vol.16, pp.40-44, (2001)).

However, even the polypeptide disclosed in the above reference does not have enough immunogenicity to induce the production of the antibody. Therefore, the above problems of conventional peptide

vaccines have not still been solved. Japanese Patent Publication Kokai No. 504,118/96 discloses a synthesized peptide vaccine enabling to prevent infection of *Chlamydia trachomatis*, which designed by linking a B cell epitope to the carboxyl terminal side of a T cell epitope. However, the vaccine did not satisfactorily induce the production of the antibody when permucosally administered.

Under the above circumstance, the object of the present invention is to provide a peptide vaccine, which satisfactorily induces the production of an antibody in living bodies and safely applicable to living bodies even when permucosally administered.

#### DISCLOSURE OF THE INVENTION

The present inventor has studied a polypeptide enabling to more strongly induce the production of an antibody, which effectively prevents infection of dental caries causing microorganisms by a model system using a peptide fragment of PAC from *Streptococcus mutans* known as one of the microorganisms to solve the above problems.

The present invention is to provide a polypeptide designed by linking a cell attachment motif of cellular adhesive molecule to the peptide having a T-cell epitope at the amino terminal side of the linker peptide and a B-cell epitope at the carboxyl terminal side of the linker peptide to solve the above problems. As a result, the present inventor found that a polypeptide, which comprises (i) an amino acid sequence in the N-terminal region of a peptide, comprising a T cell epitope, restricted by MHC class II haplotypes in whole; (ii) another amino acid sequence comprising a B cell epitope for inducing antibody in the C-terminal region of the peptide, which is located in

the peptide via an amino acid sequence, as a linker peptide, recognized by a protease, which is inserted between the two amino acid sequences (i) and (ii); and a peptide comprising an amino acid sequence(s) homologous to a cell attachment motif(s), which is linked  
5 to the peptide; and found that the polypeptide is one with a relatively high safeness, which sufficiently induces an antibody specific to the aimed antigen in terms of MHC class II haplotypes, less forms antibodies other than the aimed one, and dose not substantially induce side effects such as anaphylaxis when  
10 permucosally administered, for example, in an intranasal manner in the absence of immunological adjuvant.

The present invention provides a polypeptide designed by inserting a cell attachment motif of a cellular adhesive molecule to a peptide having a T cell epitope at the N-terminus of the linker  
15 peptide and B cell epitope at the C-terminus of the linker peptide to solve the above problems.

#### THE BEST MODE FOR CARRYING OUT THE INVENTION

20 The term "antibody" as referred to as in the present invention means immunoglobulin G (IgG), immunoglobulin M (IgM), and immunoglobulin A (IgA), and includes those secreted intranasally, orally, orbitally and intestinally as well as in the blood and the fluids body.

25 The B cell epitope sequence in the polypeptide of the present invention consists of an amino acid sequence of B cell epitope and optional other sequences to induce objective antibodies. It can be freely selected from B cell epitopes of various antigens such as

toxins, allergens, enzymes, cell surface antigens, and tumor specific antigens from microorganisms, normal cells, and tumor cells. It also can be selected from antigenic epitopes disclosed literally or identified newly by a usual immunizing method using a partial peptide as long as it actually exerts antigenicity against living bodies. It can be selected from the same antigens having T cell epitopes (described below) used in the polypeptide of the present invention. In addition, it can be partially or wholly shared by the T cell epitopes. Therefore, any amino acid sequence having a B cell epitope can be freely selected from antigenic polypeptides, varying depending on the purposes of the objectively induced antibodies. Such purposes are examples of prevention of infection; prevention or treatment of cancers, tumors, ulcers, inflammatory diseases such as hepatitis, immunological diseases such as allergy and atopic dermatitis; neutralization of enzymes; and detection for various antigens used in a clinical test or the like. For example, the PAc peptide fragment described above (reported by Nishizawa. T., Imai, S., and Hanada, N., *Japanese Vaccine conference program abstract*, p.77, (2000)) consists of an amino acid sequence of SEQ ID NO:1, and can be used for inducing antibodies capable of preventing dental caries. The part of B cell epitope sequence is usually composed of single B cell epitope. Desirably, such sequence can be in the form of a dimer, trimer or polymer by linking tandemly with one or more same or different B cell epitopes of the same antigen. In addition, the whole sequence of an antigen having a B cell epitope(s) can be used as the sequence. In order to enable the polypeptide of the present invention to treat a disease relating to some different antigenic proteins even in a single use, the polypeptide of the present invention can be designed to have

a tandemly-linked multiple B cell epitopes chosen from the antigens. Such polypeptide is capable of inducing the multiple productions of antibodies. In such case, B cell epitopes in the polypeptide should be separated from each other with a linker peptide described below in  
5 order to be surely processed.

The T cell epitope sequence in the polypeptide of the present invention comprise any T cell epitope as long as it is restricted by an MHC class II haplotype of objective animals such as mammals including humans, fowls, reptiles and fishes, and presented as  
10 antigens for helper T cells. The T cell epitope sequence can be selected from the amino acid sequences literally disclosed as T cell epitopes. In addition, such T cell epitopes can be newly identified by a usual method, i.e., immunization with a partial peptide of an antigen, in order to use as a T cell epitope sequence of the  
15 polypeptide of the present invention. The T cell epitopes can also be selected from the same antigens to those of above-described B cell epitopes used in the polypeptide of the present invention. In addition, it can be partially or wholly shared by the B cell epitope. The T cell epitope sequence can be composed of a single T cell epitope  
20 or some of same or different T cell epitopes tandemly linked together.

The T cell epitope sequence can exert its function even if the amino acid residues are substituted with other amino acid residues as long as agretopes (required for linking with MHC class II antigen) are conserved. Therefore, any amino acid sequence with conserved  
25 agretopes can be used as the T cell epitope sequence in the present invention. Multiagretope type polypeptide, which means a polypeptide having tandemly-arranged or overlapped agretopes restricted by multiple MHC class II haplotypes, can be more advantageously used as



the T cell epitope part of the polypeptide because it enables the polypeptide to be applicable for many patients in order to defend person from infection, or prevent or treat allergic diseases. Many basic structures or agretopes restricted by MHC class II haplotype are disclosed literally. Based on such disclosures, the polypeptide comprising the T cell epitopes can be freely designed to have T cell epitopes suitable for its use. For example, the polypeptides having tandemly-arranged or overlapped T cell epitope or agretope sequences selected from that of different kinds of animals are acceptable to some different kinds of animals.

In addition, the B cell epitope sequence described above with the tandemly-arranged or overlapped B cell epitopes can be also used to induce some kinds of antibodies simultaneously.

If a polypeptide having only T cell epitope sequences and another polypeptide having only B cell epitope sequences are immunized without coupling each other, the production of objective antibodies is not efficiently enhanced. While, if the polypeptides is produced in a manner of simply couplig the B cell epitope sequence and the T cell epitope sequence, it possibly induces undesired antibodies recognizing a linking part with the desired antibodies simultaneously. Therefore, the polypeptide of the present invention is designed to inhibit the production of the antibodies recognizing the above amino acid sequence by inserting the linker peptide comprising the amino acid sequence of a protease recognition site for the purpose of allowing the polypeptide to be enzymatically divided into two polypeptides through the processing step of antigen presentation. Therefore, the polypeptide of the present invention has satisfactory immunogenicity, and enables to selectively enhance the production of objective

antibodies specific to the B cell epitope sequence in a sufficient amount to exhibit the defending effect on living bodies without enhancing antibodies specific to the polypeptide.

5 The linker peptide used in the polypeptide of the present invention is inserted between the B cell epitope sequence and the T cell epitope sequence to couple them. Such linker peptides can be selected from protease recognition site sequences relating to antigen processing. Such sequences are examples of lysine-lysine (KK) dipeptide, lysine-arginine (KR) dipeptide and arginine-arginine (RR)  
10 dipeptide. Particularly, lysine-lysine dipeptide, which is a cathepsin B recognition site, is more desirable. If two polypeptides having a sequence overlapped T cell epitopes with B cell epitopes are linked together with a linker peptide, the resulting polypeptide enables to exert the both functions of T cell epitope and B cell  
15 epitope.

The cell attachment motif of cellular adhesive molecule used in the polypeptide of the present invention has a function to allow the polypeptide to stay on the surface of the mucosal cells for a long period. It can be selected from amino acid sequences of cell  
20 attachment motifs of cellular adhesive molecule including integrin family proteins or others. Examples of the amino acid sequences of integrin binding motif are arginine-glycine-asparagic acid (RGD: SEQ ID NO:2), arginine-glutamic acid-asparagic acid (RED: SEQ ID NO:3), leucine-asparagic acid-valine (LDV: SEQ ID NO:4), proline-histidine-  
25 serine-arginine-asparagine (PHSRN: SEQ ID NO:5), arginine-lysine-lysine (RKK: SEQ ID NO:6), and asparagic acid-glycine-glutamic acid-alanine (DGEA: SEQ ID NO:7) which are known as a cell attachment motif existing on cellular adhesive molecules such as fibronectin, collagen,

vitronectin, fibrinogen, laminin, Tat protein of human immunodeficiency virus (abbreviated as "HIV", hereinafter). Examples of the amino acid sequences of the cell attachment motifs without belonging among integrin family are tyrosine-isoleucine-glycine-serine-arginine (YIGSR: SEQ ID NO:8), isoleucine-lysine-valine-alanine-valine (IKVAV: SEQ ID NO:9), arginine-phenylalanine-tyrosine-valine-valine-methionine-tryptophane-lysine (RFYVVMWK: SEQ ID NO:10), and isoleucine-arginine-valine-valine-methionine (IRVVM: SEQ ID NO:11).

Particularly, RGD, RED, or YIGSR are desirable because they enhance the production of specific antibodies more strongly. The cell attachment motifs can be inserted at one or more positions selected from N- and C-terminus of the T cell epitope sequence and the B cell epitope sequence. They are preferably inserted into the polypeptide at N-terminus and/or C-terminus of T cell epitope sequence because of enabling to more strongly induce the production of antibodies specific to antigens having the B cell epitope sequence.

The method for producing the polypeptide of the present invention is not specifically restricted. The polypeptide can be prepared by a usual peptide synthesizing method. Optionally, the synthesized peptides can be linked each other according to *The Japanese Biochemical Societies Corporation, Sin-Seikagaku-Jikken-kouza* (New biochemical experimental Course), Vol. 1, "Tanpakushitsu (Protein) VI", pp. 3-44, (1992), published by Tokyo Kagaku Dojin Co., Ltd., Tokyo, Japan). The peptide can be synthesized using a peptide synthesizer commercialized by any manufacturers according to the attached protocols. The polypeptide can be also prepared according to conventional recombinant DNA techniques comprising the steps of; preparing a DNA coding for an amino acid sequence of the designed

polypeptide; inserting the DNA into a self-replicable vector and introducing the resultant into a host, i.e., microbes such as *E. coli*, *Bacillus subtilis*, *Actinomyces*, and yeast, animals, plants, cells or tissues thereof; or generating the transgenic animals or plants; 5 culturing or breeding the resultants; and collecting or purifying the polypeptide of the present invention by a usual method. Optionally, the polypeptide can be prepared by connecting the polypeptide with digestion sites of proteases other than that of digestion sites used for linking a T cell epitope sequence to a B cell epitope sequence, 10 expressing the resulting polypeptide, and digesting the resulting polypeptides with the proteases. The microbes, animals, or plants having the expressed polypeptides of the present invention can be freely used intact as a composition comprising the polypeptide for oral use. The polypeptide can be directly prepared according to the 15 above methods. In addition, It can be prepared by chemically binding the polypeptides prepared according to the above methods each other.

The polypeptide can be used alone or in combination with some polypeptides having the same B cell epitope. In order to simultaneously produce antibodies specific to several antigens, the 20 polypeptides of the present invention can be freely used in combination with at least two of them having different B cell epitopes corresponding to each antigen. A composition comprising one or more pharmaceutically acceptable additives can be advantageously prepared as long as it does not affect the effect of the present invention. 25 Examples of such additives are reducing or non-reducing saccharides such as glucose, maltose, trehalose, and sucrose; sugar alcohols such as sorbitol, mannitol, and maltitol; aqueous polymers such as agar, pullulan, guar gum, and gum arabic; proteins such as gelatin and silk,

and hydrolysates thereof; effective ingredients of nutrition products with health promoting benefits, medical cosmetics, and pharmaceuticals such as lipids, amino acids, buffers, stabilizers, antimicrobials, and perfumeries; and immunological adjuvants such as alum and aluminum

5 hydroxide. One or more of the above ingredients can be used alone or in combination. The form of the preparations comprising the polypeptide of the present invention is not restricted to a specific one as long as it is stably preserved for a long period. It can be freely selected from a solution, freeze-dried product, tablet, baccal,  
10 lozenge, powder, granule, cream, ointment, and syrup, varying depending on patient, administration, preservation, and transportation.

The polypeptide of the present invention or the composition as above can be included in a liposome. It can be advantageously used in combination with an accelerator for facilitating the penetration into  
15 skins or tissues, and applied by iontophoresis to facilitate the penetration into the part with antigen presenting cells. Various foods and beverages such as a tablet candy, candy, and soft drink, which comprise the polypeptide of the present invention, can be orally intaken to allow the polypeptide to be absorbed permucosally. The  
20 polypeptide can be allowed to express in living bodies by gene therapy, i.e., direct administration of an RNA coding for the polypeptide of the present invention or by introduction of a DNA coding for the polypeptide to cells.

The polypeptide allows antibody productive animals such as  
25 mammals including humans, dogs, cats, or mice, fowls including chickens and ducks, reptiles, and fishes particularly hatchery fishes to produce antibodies to constitutive proteins or toxins which are inherent to or secreted from pathogenic virus, microbes, or bacteria.

Therefore, the polypeptide effectively prevents or treats food poisonings caused by bacteria such as *bothulinum* and *E.coli* OH-157, and infectious diseases such as tetanus, diphtheria, and influenza. The polypeptide also effectively treats Alzheimer's disease which produces antibodies to amyloid  $\beta$  peptide, or it can be advantageously used in oral hyposensitization therapy for various allergy diseases or atopic dermatitis by predominantly producing specific IgG antibodies to allergens of mites, house dusts, pollens, foods, etc. The polypeptide of the present invention induces the production of IgA on mucosae and IgG in body fluids by permucosally administering into oral mucosae, nasal mucosae, orbital mucosae, guttural mucosae, vaginal mucosae, endotracheal mucosae, peritoneal mucosae, pleural mucosae, alveolar mucosae, esophagal mucosae, or alimentary mucosae such as gastric mucosae and intestinal mucosae. In addition, it can be administered subcutaneously, intracutaneously, or intramuscularly similarly in conventional vaccines, or in some cases it can be administered intravascularly. The polypeptide is useful for the production of specific antibodies to any proteins and intrinsically for antibody production against low-antigenic oligopeptides or polypeptides. Therefore, it can be advantageously used in such a manner of immunizing animals with synthesized oligopeptides for the purpose of producing antisera, and sensitizing immunocompetent cells *in vitro* as well as immunizing animal with synthesized oligopeptides for the purpose of producing monoclonal antibodies.

The polypeptide is also useful as an immunological adjuvant which induces the production of an antibody to be simultaneously administered with an antigen when administered to living bodies in combination with other antigen(s) or an antigenic protein deriving a B

cell epitope of the polypeptide. Dose of the administration of the polypeptide is not restricted to a specific one as long as it sufficiently induces the production of an antibody to other antigen administered simultaneously or an antigen deriving the B cell epitope of the polypeptide. When the induction of the production of antibody to the polypeptide of the present invention is not desired, the dose of the polypeptide is usually 10% by weight or less, preferably, 1% by weight or less, more preferably, 0.1% by weight or less to the other antigen(s).

The administration method of the polypeptide of the present invention is not restricted to a specific one as long as it surely transports the polypeptide to the desired position. For example, it can be dropped on mucosae with a dropper or syringe, ingested orally, applied on mucosae after formed in a cream or gel form, introduced into the desired position with a catheter, sprayed after formed in a mist form with a spray or nebulizer, or aspirated into the nose, trachea, or lung. An administration method using a syringe, catheter, or intravenous drip can be used when the polypeptide is administered subcutaneously, intracutaneously, intramuscularly, intravascularly, and intracoelarily such as intraperitoneally and intrapleurally. Varying depending on the activity of inducing antibody, kind of disease, administration pathway, administration method, animal to be treated/prevented, a dose of the polypeptide of the present invention is usually 0.00001 to 100 mg/kg body weight, preferably, 0.0001 to 25 mg/kg body weight, more preferably, 0.001 to 10 mg/kg body weight.

The following experiments explain the polypeptide of the present invention in more detail.

### Experiment:

For the purpose of developing the polypeptide usable as a vaccine for defending living bodies from infectious disease, the following experiments were carried out to obtain vaccine polypeptides enabling to efficiently induce the production of antibodies in a permucosal administration using a model system of the production antibodies specific to PAC (a bacterial surface protein antigen as of tooth adhesive factors) of *Streptococcus mutans* serotype C strain (a kind of pathogen causing dental caries). The amino acid sequence of SEQ ID NO:1 in the following experiments is known to have cross-reactivity to PAC molecule and be minimum unit peptide antigen (It is described as "unit peptide" abbreviated to "UP", hereinafter) that induces only antibody having antidental caries activity (reported by Senpuku H., *Infection and Immunity*, Vol.63, pp.4695-4703).

Polypeptides used in following experiments were synthesized by Fmoc method using a peptide synthesizer ("Model 350 Multiple Peptide Synthesizer" commercialized by Advanced Chemtech Corporation), and purified up to 95 % or over by reverse phase HPLC using "TSK-GEL " a column sized 1 cm in diameter and 30 cm in length, commercialized by Tohso Co., Ltd., Tokyo, Japan.

### Experiment 1:

#### Analysis of restriction of mouse MHC class II haplotype against UP

Five-week aged B10 congenic female mice, commercialized by Japan SLC Co. Ltd., Tokyo, Japan, were divided into eight groups consisting of five mice in view of difference of MHC class II haplotype. The all mice were intraperitoneally immunized with 200 µg/head of the UP and Freund's incomplete adjuvant (It is abbreviated as "FIA",



hereinafter.), and boosted with them under the same condition after two weeks. All the mice were bled after one week. And then, the resulting antisera were subjected to measuring the titer against UP or PAC by a usual ELISA method using the UP or PAC as a coating antigen.

- 5 The titers against the antigens are measured as follows; the antisera prepared of mice were serially diluted twofold and placed in microtiter plates to be subjected to measuring amount of antibodies by ELISA method using enzyme-labeled antibodies, and then, the resulting plates were subjected to measuring absorbance in 405 nm of each well
- 10 using "MULTISCAN Bichromatech", a microtiter plate reader commercialized by Labosystem Corporation. The values of titers were calculated by averaging the maximum dilution values showing that the difference between the resulting values of well coated with the antigen and that of well uncoated one is 0.1 or over. The result is
- 15 shown in Table 1. The parenthesized values followed each name of congenic mouse mean MHC class II haplotype.

Table 1:

Congenic mice	MHC class II haplotype	Titer against PAC	Titer against UP
B10.M	f	19,112	35,391
B10.D2	d	1,625	9,314
B10.BR	k	1,135	4,539
B10.SM	v	138	75
B10.S	s	138	75
B10.Y	pa	75	75
B10.G	q	75	45
B10.RIII	r	40	25

20

As evident from the result in Table 1, B10.M, B10.D2, and B10.BR congenic mice having MHC class II (H-2) haplotype f, d, and k,

respectively, demonstrated that the production of specific antibody to UP and PAC is more strongly induced than other mice did (over about tenfold). Therefore, the UP was revealed to have effective B cell epitope capable of inducing specific antibodies and effective multiple  
5 T cell epitopes essential for antigen presentation on congenic mice having either MHC class II (H-2) haplotype of d, f or k. Since the UP is responsible to some mice having a different haplotype of MHC class II (H-2) in spite of a short peptide consisting of just 13 amino acid residues, it is considered to be a multiagretope type of T cell  
10 epitope. The result shows that the polypeptide of the present invention, even if being single and short, is possible to be artificially designed to sufficiently induce the production of antibodies in some individuals having a different haplotype of MHC class II.

## 15 Experiment 2:

### Confirmation of multiagretope type T cell epitope of mouse

The above Experiment 1 confirmed presence of multiagretope type T cell epitope in the UP. Following experiment was carried out to  
20 confirm the location of functional amino acid. Valine substituted peptides were synthesized in the manner of exhaustively substituting any one of amino acid residue of UP with one valine residue, and subjected to immunizing the responsive mice to UP described above. As a result, the amino acid residues essential to induce the production  
25 of the antibodies in each mouse were deduced. Following, peptides substituted with valine residues were synthesized in the manner of substituting all of the deduced amino acid residues of UP with one valine residue, and subjected to immunizing according to the above.

The resulting antisera were subjected to measuring their titers using ELISA. The agretopes of the UP responsible to each MHC class II haplotype were determined by analyzing the efficiency of the production of antibodies. The results are shown in Table 2 all together. The Table shows the only amino acids recognized by MHC class II haplotype.

Table 2:

	1	2	3	4	5	6	7	8	9	10	11	12	13
Amino Acid Sequence of UP	Thr	Tyr	Glu	Ala	Ala	Leu	Lys	Gln	Tyr	Glu	Aal	Asp	Leu
Amino Acid relating to restriction of B10.A(a)				Ala			Lys	Gln			Ala		
Amino Acid relating to restriction of B10.D2(d)			Glu			Leu	Lys					Asp	Leu
Amino Acid relating to restriction of B10.M(f)						Leu			Tyr	Glu			Leu
Amino Acid relating to restriction of B10.BR(k)	Thr	Tyr			Ala			Gln					

10

As evident from the result in Table 2, the polypeptide consisting of 13 amino acid residues has amino acid residues essential for recognition of MHC class II haplotype (agretope) in the overlapped or shifted form. The location of amino acid recognized by each MHC class II haplotype was confirmed as a multiagretope type T cell epitope in the UP.

### Experiment 3:

#### Design of multiagretope type peptide antigen

It is investigated whether remodeling the above UP by substituting their amino acids is possible to change immunological response relating to restriction of MHC class II haplotype in mice or not. The peptide having amino acid sequence of SEQ ID NO:12 (described as "YQTEL peptide", hereinafter), SEQ ID NO:13 (described as "YETDL peptide", hereinafter), and SEQ ID NO:14 (described as "YETAL peptide", hereinafter), which are designed by changing the part corresponding to agretopes of B10.D2(d) and B10.M(f) mouse (at the position of 10 to 12 of the amino acid sequence of SEQ ID NO:1) determined in Experiment 2, amino acid sequence of SEQ ID NO:1 (described as "YEADL peptide", hereinafter), SEQ ID NO:15 (described as "YEADLKQY peptide", hereinafter), which is designed by adding lysine-glutamine-tyrosine to the amino acid sequence of SEQ ID NO:1 at the carboxyl terminal, SEQ ID NO:17 (described as "UP-PAC(305-318)", hereinafter), which is designed by linking the peptide of SEQ ID NO:16 having the amino acid sequence at the positions of 305 to 318 from amino terminal of PAC known as a T cell epitope recognized by B10.S(s) mouse (described as "PAC(305-318)", hereinafter") to amino terminal of UP, and SEQ ID NO:18 (described as "PAC(305-318)-UP", hereinafter), which is designed linking the UP and PAC(305-318) in reverse were synthesized and applied to B10 congenic mice to be immunized by the same method and schedule to Experiment 1. After two weeks from the boosting immunization, the antisera were prepared from the resulting blood samples, diluted with physiological saline 512-fold, and subjected to measuring the production of the antibodies by ELISA method according to Experiment 1. The production of antibodies in each congenic mouse was measured absorbance in 405 nm to be compared.

The result was shown in Table 3. The result of measuring the production of antibodies specific to UP in mouse immunized with UP-PAc(305-318) and PAc(305-318)-UP were shown in Table 4. The antiserum presented 0.1 or more absorbance was judged to have antibody against UP in the diluted serum.

Table 3:

Congenic mouse	MHC class II haplotype	Titer against UP (Absorbance in 405 nm)					
		YQTEL peptide	YETDL peptide	YETAL peptide	YEADL Peptide	YQADLKQY Peptide	PAc(305-318)-UP
B10.A	a	0.01	0.01	0.01	0.28	0.29	0.29
B10.D2	d	0.01	0.32	0.32	0.33	0.32	0.30
B10.M	f	0.01	0.12	0.33	0.32	0.32	0.32
B10.BR	k	0.22	0.31	0.30	0.30	0.30	0.30
B10.S	s	0.01	0.01	0.01	0.01	0.01	0.31
B10.SM	v	0.01	0.01	0.01	0.01	0.32	0.31

Table 4:

Congenic mouse	MHC class II haplotype	Titer Against The UP	
		Immunizing with UP-PAc(305-318)	Immunizing with PAc(305-318)-UP
B10.D2	d	7,610	28,695
B10.S	s	106	108,205
B10.M	f	59,986	108,205

As evident from the result in Table 3, immunizing with YQTEL peptide artificially designed from UP induced the production of the antibody for only one B10.BR(k), while immunizing with YEADL peptide (UP) simultaneously induced the production of the antibody for three kinds of mice except of B10.S(s) and B10.SM(v). It is confirmed that changing one to three amino acids is effective to change the immunological responsibility for different individuals in view of MHC class II haplotype. YEADLKQY peptide, which is designed by adding

lysine-glutamine-tyrosine to the UP, induced the production of antibody for four kinds of mice other than B10.S(s). Further, as evident from the results in Table 3 and 4, PAC(305-318)-UP which is designed by linking PAC(305-318) responded by B10.S(s) mouse  
5 irresponsible to the UP to the amino terminal of the UP, was confirmed to be a multiagretope type peptide antigen capable of inducing the production of the antibody for five kinds of mice including s type. Therefore, the above results revealed that artificially designing the polypeptide having the overlapping amino acid sequence restricted by  
10 each MHC class II haplotype based on the analysis of the amino acid sequence relating to more than one MHC class II haplotype restrictions on the antigen, enables to construct overlapping type of multiagretope type T cell epitope, which efficiently induces the production of the antibody to the antigen and is simultaneously restricted by more than  
15 one MHC class II haplotypes. The polypeptide designed by linking more than one T cell epitopes tandemly, so-called as "cluster type T cell epitope", is confirmed to be T cell epitope capable of efficiently inducing the production of the antibody as well as overlapping type epitope for individuals having more than one MHC class II haplotype  
20 restrictions. As evident from the result in Table 4, it is observed that the polypeptide designed by linking the UP to C-terminal side of PAC(305-318) more strongly induces the production of antibodies rather than the polypeptide designed by linking the UP to N-terminal side of PAC(305-318).

25

#### Experiment 4:

Artificial construction for multiagretope type peptide antigen for human use

Under the above result of experiment 3, in order to solve a problem of the individual difference due to MHC class II haplotype restriction, an overlapping multiagretope peptide (abbreviated as "OMP", in the following Experiments) having amino acid sequence of SEQ  
5 ID NO:19, which is responsible for more than one class II haplotypes, was constructed based on some preiously disclosed human restriction motifs of MHC class II haplotype (HLA-DR) against T cell epitopes. The peptide is capable of exerting for mouse the same function to human as T cell multiagretope (data not shown). Following Table 5  
10 shows the amino acid recognized by each human MHC class II HLA-DR haplotypes.

Table 5:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amino Acid Sequence of OMP	Leu	Ala	Val	Tyr	Trp	Glu	Leu	Leu	Ala	Lys	Tyr	Leu	Leu	Asp	Arg	Val	Gln	Lys	Val	Ala
Amino Acid relating to restriction of HLA-DR1				Tyr			Leu		Ala			Leu								
Amino Acid relating to restriction of HLA-DR3			Val			Glu														
Amino Acid relating to restriction of HLA-DR4											Tyr			Asp		Val	Gln			
Amino Acid relating to restriction of HLA-DR5													Leu		Arg	Val		Lys		
Amino Acid relating to restriction of HLA-DR6													Leu		Arg	Val		Lys		Ala
Amino Acid relating to restriction of HLA-DR7				Tyr			Leu					Leu								
Amino Acid relating to restriction of HLA-DR8													Leu			Val		Lys		
Amino Acid relating to restriction of HLA-DR11					Trp			Leu		Lys										



Experiment 5:

Influence of linker peptide for enhancing the production of antibodies specific to the polypeptide

The UP prepared in Experiment 3 does not have sufficient immunogenicity due to a too short peptide. In order to enhance its immunogenicity, tandemly linked polypeptides were tested. However, if the UPs were simply linked each other, the resulting peptides were concerned to have a new epitope sequence inducible of new antibodies at the linking part. For the purpose of allowing the only desired B cell epitope sequence to present, a linker peptide was arranged between the T cell epitope sequence and B cell epitope sequence. Such linker peptide is KK, which is previously disclosed as recognition site of endosome protease cathepsin B relating to the processing of antigen in antigen presenting cell. Following experiment is to confirm the influence of the linker peptide for enhancing the production of antibodies.

The polypeptides designed by inserting with KK between OMP and UP, represented by "OMP-KK-UP" having amino acid sequence of SEQ ID NO:20 and "UP-KK-OMP" having amino acid sequence of SEQ ID NO:21, respectively, were synthesized. The OMP was prepared in Experiment 4 and had a mouse T cell epitope, and the UP comprised a B cell epitope.

They were immunized to BALB/c mice intraperitoneally by the method according to Experiment 1. The serum was prepared from mice and titers against OMP, the immunized polypeptide, and PAC were measured by the method according to Experiment 1. The result is shown in Table 6.

Table 6:

Polypeptide used as an antigen	Titer against PAc	Titer against the Immunized peptide	Titer against OMP
OMP-KK-UP	836,462	782,685	1,731
UP-KK-OMP	961	29,921	1,211

As evident from the result in Table 6, OMP-KK-UP; arranging T cell epitope sequence at N-terminal region and B cell epitope sequence at C-terminal region and inserting a linker peptide between the two sequences; was revealed to efficiently induce the production of antibodies. This tendency was also observed in other strains of mice.

Particularly, such tendency was remarkably observed in B10.S(s) mouse which PAc(305-318) was functional as a T cell epitope but UP was not so (referred to Table 4). It was revealed that the peptide at N-terminal side of the linker peptide is more effectively recognized as T cell epitope and the peptide at carboxyl terminal of the linker peptide is more effectively recognized as B cell epitope.

#### Experiment 6:

#### Effect of a cell attachment motif of cell adhesive molecule on the enhancement of intranasal immunogenicity of a peptide antigen

A polypeptide having SEQ ID NO:22, arranged with two molecule of the UP, which has the amino acid sequence of SEQ ID NO:1 and induces the production of the antibodies having antitumoral activity, with the linker, lysine-lysine, (described as "di unit peptide" and abbreviated as "DUP", hereinafter) is so efficiently capable of enhancing the production of antibodies to need no immunological adjuvant in the case of injection use (subcutaneously or

intraperitoneally). However, in the case of intranasal immunization, it is insufficient to use singly and actually needs an immunological adjuvant. In order to enhance the intranasal immunogenicity of the DUP, a cell attachment motif, which is possible to retain the DUP on mucosae for a long period, was introduced in the DUP. Such cell attachment motif was selected from integrin binding motifs of cell adhesion proteins such as fibronectin, laminin and collagen, which were determined to have a cell adhesion property. The following experiment was carried out to confirm the influence of the cell attachment motif on the immunogenicity. At first, the polypeptides having one or more cell attachment motif selected from RGD, RED, LDV, PHSRN, RKK, DGEA, YIGSR, IKVAV, IRVVM, and RFYVVMWK, at the N-terminal region were synthesized. As a negative control, DUP was prepared. As controls, polypeptides having DUP and either DRE (SEQ ID NO:23), DED (SEQ ID NO:24) or HAV (SEQ ID NO:25), which are amino acid sequences relating to cadherin without showing cell adhesion property in single use, were synthesized. Five week-aged female BALB/c mice, commercialized by Japan SLC, Inc., Shizuoka, Japan, were intranasally administered with 4  $\mu$ l of phosphate buffer saline (hereinafter, abbreviated as "PBS") or distilled water containing 50  $\mu$ g of each sterilized polypeptide in a manner of dropping by 2  $\mu$ l into both nostrils. Mice of the negative control were administered with DUP alone. Mice of a positive control were administered with the DUP and 1  $\mu$ g of CT. The DUP and the polypeptide having DUP and RGD were also intraperitoneally administered. After two weeks from the first immunization, the same polypeptide as a booster was administered again in the same manner. After two weeks from the second immunization, the same polypeptide as a booster was administered again in the same

manner. After one week from the third immunization, sera were prepared from mice and subjected to measuring the titers of antubodies against PAC, DUP, CT and the polypeptide having the DUP and cell attachment motifs using the ELISA method according to Experiment 1.

5 In order to confirm the effect of RGD or YIGSR sequence, a peptide fragment consisting of RGDS (SEQ ID NO:26) or YIGSR (SEQ ID NO:27) as an inhibitor against polypeptides having RGD or YIGSR sequence was applied together with the polypeptide to the mice in an excess amount to immunize the mice. The results are shown in Table 7. The mice  
10 immunized with the polypeptides having one or more motifs selected from RGD, RED, LDV, PHSRN, RKK, DGEA, YIGSR, IKVAV, IRVVM and RFYVVMWK showed the effect on the enhancement of the production of the antibodies specific to the UP. While, the mice immunized with the polypeptide having DRE, DED or HAV did not show such effect. The  
15 results of DUPs such as SEQ ID NO:27 ("RGD-DUP", hereinafter), SEQ ID NO:28 ("RED-DUP", hereinafter), SEQ ID NO:29 ("YIGSR-DUP", hereinafter), SEQ ID NO:30 ("DED-DUP", hereinafter) and SEQ ID NO:31 ("HAV-DUP", hereinafter) are typically shown in Table 7.

Table 7:

Polypeptide used as an antigen	Administration	Titer against PAC
DUP	Intranasal administration	640
CT + DUP		32,768
RGD-DUP		5,069
RGDS + RGD-DUP		256
RED-DUP		1,395
YIGSR-DUP		1,195
YIGSR + YIGSR-DUP		235
DED-DUP		544
HAV-DUP		320
DUP	Intraperitoneal administration	312
RGD-DUP		2,352

20

As evident from the result in Table 7, UP was not observed to

induce the production of antibodies specific to the UP when intranasally administered in single use. While, the polypeptide having RGD or RED sequence as integrin attachment motif, or YIGSR as an attachment motif of laminin against laminin binding protein, i.e.,  
5 RGD-DUP, RED-DUP, or YIGSR-DUP, was observed to have the effect on enhancing the production of antibodies. Adding an excess amount of RGDS or YIGSR peptide fragment, which is a short peptide as an inhibitor of binding to integrin, inhibited the production of antibodies specific to the Pac. The result suggested that cell  
10 attachment motif such as RGD and YIGSR is effective on more strongly inducing the production of antibodies, and the effect exerted by binding the DUP to integrins on cell surface of mucosae.

#### Experiment 7:

#### 15 Influence of cellular adhesive molecule for enhancement of the production of antibodies by permucosally administered peptide vaccine

Following experiment is to investigate influence for enhancement of other peptide antigen by addition of integrin binding motif demonstrated in Experiment 6 and due to the position of the motif.  
20 Four kinds of the polypeptides; "RGD-OMP-KK-UP" (SEQ ID NO:32); "OMP-RGD-KK-UP" (SEQ ID NO:33); "OMP-KK-RGD-UP" (SEQ ID NO:34); "RGD-KK-UP-RGD" (SEQ ID NO:35) were synthesized in the manner of introducing RGD sequence into "OMP-KK-UP" at the positions of N-terminal or C-terminal side of the OMP or the UP; Wherein the RGD sequence was a kind of  
25 integrin binding motif and is suggested to enhance the production of antibodies specific to the polypeptide according to Experiment 6, and wherein the "OMP-KK-UP" was confirmed to be high enhancement of production of the specific antibody to Pac according to Experiment 5.

As a positive control, CT is used, which is previously disclosed to have an adjuvant activity in permucosal administration. B10 mice were immunized with solutions containing each polypeptide with or without CT according to Experiment 6, and then, effects of each peptide on enhancing the production of antibodies were judged. The result is shown in Table 8.

Table 8:

Polypeptide used as an antibody	Titer against PAC	Titer against the immunized peptide	Titer against OMP
OMP-KK-UP	32	128	32
CT + OMP-KK-UP	1,454	1,063	14
RGD-OMP-KK-UP	11,544	11,514	32
OMP-RGD-KK-UP	26,241	24,370	16
OMP-KK-RGD-UP	169	723	16
OMP-KK-UP-RGD	1,981	9,483	16

10

As evident from the result shown in Table 8, the insertion of RGD into OMP-KK-UP peptide enhanced the production of antibodies specific to PAC. Particularly, in the case of the inserting RGD at the position of N-terminal or C-terminal side of OMP, in other words, in N-terminal side from the linker, the polypeptide more remarkably enhanced the production of antibodies rather than the polypeptide having no RGD with CT. The almost of produced antibodies were capable of reacting to PAC. While, the polypeptides having RGD in C-terminal side from the linker induced many antibodies specific to the peptide including RGD sequence.

20

From above-described, the sequence of N-terminal side from the linker is recognized as T cell epitope, and the sequence of C-terminal side from the linker is recognized as B cell epitope in the presence

of no adjuvant in intranasal immunization. The polypeptide efficiently enhances the production of antibodies specific to objective B cell epitope sequence. Particularly, it is revealed that the polypeptide having RGD sequence in N-terminal side from the linker is capable of inducing the antibodies specific to only PAc.

#### Experiment 8:

#### Generality of basic design of peptide vaccine for permucosal administration

Following experiment is to investigate influence for the production of antibodies specific to B cell epitope sequence in the case of replacing T cell epitope or B cell epitope of the polypeptide constructed as RGD-(T cell epitope)-KK-(B cell epitope) according to Experiment 7 by placing other sequence instead of OMP or UP. The polypeptide represented by "RGD-OMP-KK-UP" (SEQ ID NO:38) or "T1-RGD-KK-UP" (SEQ ID NO:39) were designed and synthesized using T1 peptide (SEQ ID NO:36; which has been reported to be restricted to various MHC class II haplotypes and a multiagretope type T cell epitope derived from HIV IIIB gp120, reported by Ahlers J.D., *Proceedings of the National Academy of Sciences USA*, Vol.94, No.20, pp.10856-10861, (1997)) as T cell epitope and OVA peptide fragment (hereinafter, abbreviated as "OVAp") consisting of 14 amino acid residues (SEQ ID NO:38; which is previously disclosed to induce the production of antibodies specific to ovalbumin, abbreviated as "OVA") for BALB/c mouse, reported by Hunt D.F., *Science*, Vol.256, pp.1817-1820, (1992). "OMP-KK-OVAp" (SEQ ID NO:40) and "T1-KK-UP" (SEQ ID NO:41) were prepared as controls. BALB/c mice were intranasally immunized with each above polypeptide according Experiment 6. The result is shown in

Table 9.

Table 9:

Polypeptide used as an antibody	Titer against OMP	Titer against the immunized peptide	Titer against OVA	Titer against CT
OMP-KK-OVAp	108	1,589	1,656	-
RGD-OMP-KK-OVAp	235	5,080	11,692	-
CT + OMP-KK-OVAp	7,319	21,310	25,654	3,656,835
Polypeptide used as an antibody	Titer against T1	Titer against the immunized peptide	Titer against Pac	Titer against CT
T1-KK-UP	103	160	320	-
T1-RGD-KK-UP	107	1,707	1,579	-
CT + T1-KK-UP	69	1,152	176	139,264

\*"-": Not tested

5

As shown in Table 9, the mice immunized intranasally with RGD-OMP-KK-OVAp or T1-RGD-KK-UP showed a remarkable enhancement of the production of antibodies specific to OVA or Pac. It is confirmed that insertion of RGD sequence imparted the polypeptide to more strongly enhance the production of antibodies than polypeptides having no RGD sequence.

10

#### Experiment 9:

#### 15 Effect of the polypeptide of the present invention on enhancement of the production of antibodies specific to other antigen

CT, usually used as an adjuvant, is known to strongly induce antibodies specific to not only CT but also other antigens when permucosally administered together with the other antigens. Otherwise, the polypeptide of the present invention such as RGD-OMP-KK-UP, OMP-RGD-KK-UP, RGD-OMP-KK-OVAp, and T1-RGD-KK-UP induced specific antibodies even without CT. Following experiment is to investigate

20



whether the polypeptide enhances the production of antibodies specific to other antigens or not.

Influence of various polypeptides for the production of antibodies specific to bovine serum albumin in intranasal administration

5 BALB/c mice were immunized with a physiological saline solution containing 4 µg of bovine serum albumin (hereinafter, abbreviated as "BSA") and either of 1 µg of DUP, RGD-DUP, OMP-KK-UP, OMP-RGD-KK-UP, OMP-KK-OVAp or RGD-OMP-KK-OVAp, or 2 µg of CT in intranasal  
10 administration according to Experiment 6, and titers in the blood were measured. The result is shown in Table 10. Titers of antibodies against BSA, co-administered peptides, and CT were measured.

Influence of various polypeptides for antibody production against ovalbumin in intranasal administration

15 B10.D2 or BALB/c mice were immunized with a physiological saline solution containing 4 µg of OVA and either of 1 µg of OMP-RGD-KK-UP, OMP-RGD-KK-OVAp, or 2 µg of CT in intranasal administration according to Experiment 6, and then, titers in the blood were measured. The  
20 result is shown in Table 10. Titers of antibodies against OVA, OMP-RGD-KK-OVAp, and CT were measured.

Table 10:

Polypeptide used as an antibody		Titer against CT	Titer against BSA	Titer against the immunized peptide
BSA		-	32	-
CT + BSA		1,887,437	838,861	
DUP + BSA		-	179	83
RGD-DUP + BSA			6,912	154
RGDS + RGD-DUP + BSA			576	128
OMP-KK-UP + BSA			20,480	1,152
OMP-RGD-KK-UP + BSA			109,227	213
OMP-KK-OVAp + BSA			1,441,792	224
RGD-OMP-KK-OVAp + BSA			1,527,887	256
Polypeptide used as an antibody		Titer against CT	Titer against OVA	Titer against the immunized peptide
B10.D2 mouse	OVA	-	203	-
	CT + OVA	681,574	24,576	
	OMP-RGD-KK-UP + OVA		-	10,242
BALB/C mouse	OVA	524,288	16	-
	CT + OVA		4,096	
	OMP-RGD-KK-UP + OVA		-	2,176

\*"-": Not tested

5 As shown in Table 10, antibodies specific to BSA or OVA were hardly induced in the blood of the mice when intranasally administering BSA or OVA alone. In contrast, mice immunized with BSA or OVA in combination with OMP-RGD-KK-UP, OMP-KK-OVAp or RGD-OMP-KK-OVAp showed a strong enhancement of the production of antibodies

10 specific to BSA or OVA. In addition, mice immunized with BSA in combination with RGD-DUP or OMP-KK-UP showed the production of antibodies specific to BSA than. However, latter mice showed lower enhancement than former mice. Mice immunized with BSA or OVA in combination with CT showed the same degree of the production to the

15 above mice. Mice immunized in combination with 1  $\mu$ g of OMP-RGD-KK-UP, OMP-KK-OVAp, or RGD-OMP-KK-OVAp showed a slight production of

antibodies specific to the peptide, in contrast, mice immunized in combination with 2 µg of CT showed strongly enhancement of the production of antibodies specific to CT. Therefore, OMP-RGD-KK-UP, OMP-KK-OVAp, or RGD-OMP-KK-OVAp is confirmed to be useful for inducing  
5 antibodies specific to other antigens as an immunological adjuvant in the manner of using them in an insufficient or small amount to be induce the production of their antibodies.

As described above, it is confirmed that cell attachment motifs are allowed the polypeptide consisting of B cell epitope connected to  
10 T cell epitope with protease recognition site such as KK to enhance antibody production against B cell epitope. The polypeptide of the present invention is useful as inducers for specific antibody production or enhancer for antibody production because it is efficiently capable of inducing antibody production against B cell  
15 epitope peptide in the polypeptide except inducing useless antibody production against other site than B cell epitope even when administered without immunological adjuvant intranasally. As the result that living bodies administered with the polypeptide efficiently produce antibody against antigenic protein deriving the B  
20 cell epitope used for immunizing, the polypeptide of the present invention is capable of inducing various antibody such as antibody for preventing infectious, antibody for neutralizing toxin or enzyme active center, and antibody against allergen in the presence of no immunological adjuvant in mucosal immunization including nasal  
25 immunization. The polypeptide is useful as peptide vaccine for intranasally immunizing in order to prevent infection. The polypeptide effects immunological adjuvant when administered with other antigen together.

The following examples explain the polypeptide of the present invention concretely, but the present invention must not be restricted by these examples.

5    Example 1

Composition for enhancing the production of antibodies specific to PAC

10    The syrup agent containing the polypeptide prepared in Experiment 7 was obtained by dissolving 100 µg/ml of any one of RGD-OMP-KK-UP, RGD-OMP-KK-UP, RGD-OMP-KK-UP, or OMP-KK-UP, and 40% of αα-trehalose (reagent grade, commercialized by Hayashibara Biochemical Laboratories, Inc., Okayama, Japan) in distilled water, sterilizing by a usual method. The resulting syrup was placed by 2 ml into sterilized vials, and sealed. Since the product is stable and restricted by various MHC class II haplotypes, it exerts the effect of  
15    vaccine which enhances to produce the antibody having the effect on preventing dental caries. The product can also be useful as immunological adjuvant which enhances the antibody against other antigen when permucosally and intracutaneously administered with the polypeptide together.

20

Example 2

Composition for enhancing the production of antibodies specific to PAC

25    Agent containing the polypeptide prepared in Experiment 7 was obtained by dissolving 10 µg/ml, 100 µg/ml or 1,000 µg/ml of RGD-T1-KK-UP in physiological saline containing 1%(w/v) of sucrose, and sterilizing by filtration. The resulting solution was placed by 1 ml into sterilized vials, freeze-dried, and sealed in a usual manner. The product is a preparation for permucosal administration or

infection, which is stable and has a satisfactory effect on preventing dental caries. The product is used after dissolved in 1 ml of distilled water for injection. Since the product is stable and restricted by various MHC class II haplotypes, it exerts the effect of vaccine, which efficiently enhances the production of the antibodies having the effect on the prevention of dental caries, in intranasal or oral administration for many human or animals. The product can also be useful as an immunological adjuvant which enhances the production of other antibodies specific to other antigens when permucosally and intracutaneously administered together with the other antigens.

#### Example 3

##### Toxicity test for composition containing the polypeptide

LD<sub>50</sub> of the preparation containing the polypeptide, prepared in Example 1 or 2, was investigated by administering five week-aged DDY male mice with the physiological saline containing 12.5 mg/ml of any one of the polypeptides and 0.5% of sucrose orally, intraperitoneally, or intramuscularly according to a usual method. As a result, both of the LD<sub>50</sub> of the preparations were 100 mg (peptide weight) /kg mouse body weight or over. Therefore, the preparations are considered as safe preparations with no toxicity when administered to humans or animals.

#### Example 4

##### Composition for enhancing the production of antibodies specific to HIV

Any one of OMP, T1, gag protein at the position of 298-312 (SEQ ID NO:42) and pol protein at the position of 596-610 (SEQ ID NO:43) was selected as a T cell epitope sequence. The gag protein and pol

protein were reported as T cell epitopes restricted by HLA-DR1-9 or 51-53, by Wilson, C. C., *Journal of Virology*, Vol.75, pp.4195-4207, (2001). The polypeptides of the present invention were designed in a manner of arranging RGD sequence at N-terminal or C-terminal region of either of the T cell epitope sequences, and then, arranging B cell epitope sequence of V3 loop peptide of gp120 protein from HIV (SEQ ID NO:44), reported by Haynes, B. F., *The Journal of Immunology*, Vol.151, pp.1646-1653, (1993), at the C-terminal region of the resulting sequence, which positions via KK linker inserted between the two sequences. 150 µg/ml of the one or two of the above polypeptides and 100 mg/ml of mannitol were dissolved in physiological saline. The resulting solutions were placed by 1 ml in 5 ml-volume vials and freeze-dried. The product is useful as a vaccine for inhibiting the spreading of HIV and delaying the development of HIV because it is capable of efficiently enhancing the production of antibodies specific to HIV in permucosal or percutaneous administration. In addition, it enables to target for variety person because of restricted to various MHC class II haplotypes. The product is also useful as immunological adjuvant for enhancing the production of other antibodies specific to other antigens which is permucosally administered together with the other antigens.

#### Example 5:

#### Composition for enhancing antibody production against influenza virus

The polypeptides of the present invention were designed in a manner of arranging RGD or YIGSR sequence at N-terminal or C-terminal region of the T cell epitope sequence selected from OMP, T1, SEQ ID NO:42 and 43, and then, in order to induce neutralizing antibodies

against an influenza virus, arranging B cell epitope sequence of HA (hemaggrutinin) protein at the position of 91 - 108 from influenza virus (SEQ ID NO:45) reported by Ben-Yedidia T., *Molecular Immunology*, Vol.39, pp.323-331, (2002) at the C-terminal region of the resulting sequence, which positions via KK linker inserted between the two sequences. Each 75 µg/ml of one or more the above peptides was admixed with physiological saline containing 0.5 mg/ml of human albumin. The resulting solutions were placed by 1 ml in 5 ml-volume vials and freeze-dried in a usual manner. The product is useful as a vaccine for inhibiting the infection of influenza virus because it is capable of efficiently enhancing the production of the antibodies specific to influenza virus in permucosal or percutaneous administration. In addition, it is enabling to target for variety person because of restricted to various MHC class II haplotypes. The product is also useful as immunological adjuvant for enhancing the production of other antibodies specific to other antigens, when applied together with the other antigens in permucosal administration.

Example 6:

Papilloma virus vaccine

The polypeptides of the present invention were designed in a manner of arranging RGD sequence at N-terminal or C-terminal region of the T cell epitope sequence selected from OMP, T1, SEQ ID NO:42 and 43, and then, in order to induce neutralizing antibodies against human papilloma virus, arranging B cell epitope sequence of L2 protein (SEQ ID NO:45) from human papilloma (SEQ ID NO:46), reported by Kawana K., *Vaccine*, Vol.19, pp.1496-1502, (2001), at the C-terminal region of the resulting sequence, which positions via KK linker inserted between the

two sequences. Each 200 µg/ml of one or more the above peptides was admixed with phosphate buffer saline containing 0.25 mg/ml of gelatin.

The resulting solution was placed by 0.5 ml in 5 ml-volume vials and freeze-dried in a usual manner. The product is useful as a vaccine  
5 for inhibiting the infection of human papilloma virus because it is capable of efficiently enhancing the production of antibodies specific to human papilloma virus in permucosal or percutaneous administration.

In addition, it enables to target for variety person because of restricted to various MHC class II haplotypes. The product is also  
10 useful as immunological adjuvant for enhancing the production of other antibodies specific to other antigens when applied together with the other antigens in permucosal administration.

Example 7:

15 Composition for the production of antibodies specific to OVA

100 µg/ml of RGD-OMP-KK-OVAp prepared in Experiment 8 was dissolved with 40% of α,α-trehalose (reagent grade, commercialized by Hayashibara Biochemical Laboratories, Inc., Okayama, Japan) in distilled water and sterilized in a usual manner. The resulting syrup  
20 was placed by 2 ml in sterilized vials, and sealed to obtain a syrupy vaccine containing the polypeptide. The product is satisfactorily stable, and efficiently enhances the production of the antibodies specific to OVA when intranasally, orally or percutaneously administered to animals. The product can also be useful as  
25 immunological adjuvant which enhances the antibody against other antigen when intranasally administered with the polypeptide together.

Example 8:



Composition for enhancing the effect of influenza vaccine on the production of antibodies

4 µg of either commercialized influenza HA vaccine by Astellas Pharma Inc., Tokyo, Japan, or virus surface antigenic protein such as HA and M protein was dissolved with 1 µg of either RGD-OMP-KK-OVAp or RGD-OMP-KK-UP in 1 ml of physiological saline. The resulting solutions were placed by 0.5 ml in sterilized vials and sealed to obtain pharmaceutical preparations. The product containing the usual influenza vaccine or the viral surface antigenic protein, which dose not induce by permucosal administration in single use, strongly induces the production of antibodies specific to the viral surface antigenic protein due to the immunological adjuvant-like action of RGD-OMP-KK-OVAp or RGD-OMP-KK-UP. The product can be used as a vaccine, which strongly induces the production of the antibody having an activity for preventing the infection of influenza virus when intranasally administered three or four times at two weeks interval.

Example 9:

Oral composition for hyposensitization of Japanese cedar pollinosis

The polypeptides of the present invention were designed in a manner of arranging RGD sequence at N-terminal or C-terminal region of the T cell epitope sequence selected from OMP, T1, SEQ ID NO:42 and 43, and then, in order to induce the production of antibodies specific to Japanese cedar pollen allergens, arranging B cell epitope sequences "VHPQDGDA" of Cry j 1, reported by Kawana K., Vaccine, Vol.19, pp.1496-1502, (2001) and "KWVNGRI" of Cry j 2, reported by Tamura Y., Clinical and Experimental Allergy, Vol.33, No.2, pp.211-217, (2003), at the C-terminal region of the resulting sequence, which positions

via KK linker inserted between the two sequences to obtain the polypeptide consisting of the amino acid sequence of SEQ ID NO:47. Each 200 µg/ml of one or more the above peptides was admixed with phosphate buffer saline containing 0.25 mg/ml of gelatin to obtain an oral composition for hyposensitization of Japanese cedar pollinosis. The product is useful as a preparation for hyposensitization of Japanese cedar pollinosis because it is capable of efficiently enhancing the production of IgG antibodies specific to Cry j 1 and Cry j 2 in permucosal or percutaneous administration. In addition, it enables to target for variety person because of restricted to various MHC class II haplotypes.

#### INDUCTRIAL APPLICABILITY

As described above, the present invention relates to the polypeptide containing a special antigen peptide, which enables to enhance the production of an antibody specific to antigenic epitope of an objective antigen or a composition thereof without immunological adjuvant. The polypeptide of the present invention is useful as vaccine in use for many person as well as antibody productive animals such as mammals, fowls, reptiles, and fishes, or as antigen for enhancement of specific antibody production because it is capable of using in permucosal administration such as intranasal and oral administration more easy and safe than percutaneous injection and is restricted in varieties of MHC class II haplotypes. It is also useful as immunological adjuvant for enhancing the production of antibodies specific to other antigens when administered together with the other antigens.